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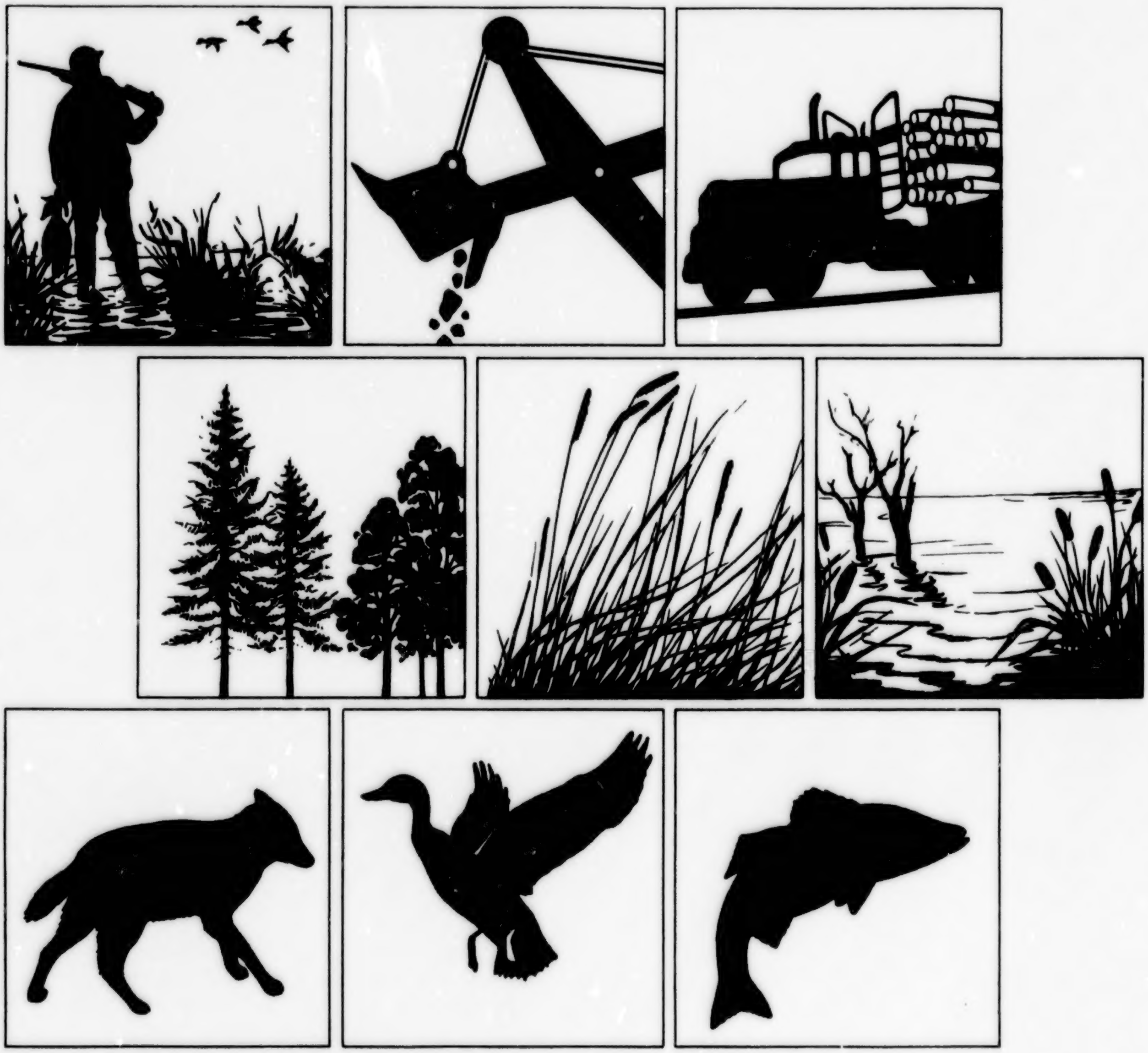
BIOLOGICAL REPORT 89(4)
OCTOBER 1988

GUIDANCE FOR MODELING CAUSES AND EFFECTS IN ENVIRONMENTAL PROBLEM SOLVING



Fish and Wildlife Service

U.S. Department of the Interior

Biological Report 89(4)
October 1988

GUIDANCE FOR MODELING CAUSES AND EFFECTS IN ENVIRONMENTAL PROBLEM SOLVING

by

Carl L. Armour
and
Samuel C. Williamson
U.S. Fish and Wildlife Service
National Ecology Research Center
2627 Redwing Road
Fort Collins, CO 80526-2899

U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

Suggested citation:

Armour, C.L., and S.C. Williamson. 1988. Guidance for modeling causes and effects in environmental problem solving. U.S. Fish Wildl. Serv. Biol. Rep. 89(4). 21 pp.

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ACKNOWLEDGMENTS

Many ideas for preparing this document originated from workshop experiences. Participants in the workshops included staff from U.S. Fish and Wildlife Service field offices in Annapolis, Maryland; Daphne, Alabama; and East Lansing, Michigan. Additional participants were associated with the Wyoming Cooperative Fish and Wildlife Research Unit, National Wetlands Research Center, and Great Lakes National Fisheries Center.

Mary Sanz prepared the graphics and Patricia Gillis typed the manuscript. A special acknowledgment is given to Charles Peterson who initially demonstrated use of cause and effect modeling to us.

INTRODUCTION

Environmental problems are difficult to solve because their causes and effects are not easily understood. When attempts are made to analyze causes and effects, the principal challenge is organization of information into a framework that is logical, technically defensible, and easy to understand and communicate. When decisionmakers attempt to solve complex problems before an adequate cause and effect analysis is performed there are serious risks. These risks include: greater reliance on subjective reasoning, lessened chance for scoping an effective problem solving approach, impaired recognition of the need for supplemental information to attain understanding, increased chance for making unsound decisions, and lessened chance for gaining approval and financial support for a program.

Cause and effect relationships can be modeled. This type of modeling has been applied to various environmental problems, including cumulative impact assessment (Dames and Moore 1981; Meehan and Weber 1985; Williamson et al. 1987; Raley et al. 1988) and evaluation of effects of quarrying (Sheate 1986). This guidance for field users was written because of the current interest in documenting cause-effect logic as a part of ecological problem solving. Principal literature sources relating to the modeling approach are: Riggs and Inouye (1975a,b), Erickson (1981), and United States Office of Personnel Management (1986).

APPLICATIONAL PREREQUISITES

Use of the approach requires development of a model of causes and effects associated with a problem. Successful application of the method depends on seven prerequisites (Table 1). For prerequisite 1, it must be understood that all approaches have strengths and weaknesses, and there is no practical way to accurately evaluate all complex interactions contributing to a problem. Given the analytical difficulties, the best approach for avoiding rejection of results is to disclose method limitations (e.g., assumptions that must be accepted). Then, there will be a basis for negotiating conflicts that might arise.

Concerning prerequisite 2, valuable time can be wasted until agreement on the real problem is attained through frustrating trial and error efforts. To ensure that the correct problem is chosen from the outset, involve a core group of specialists in a scoping session to discuss, debate, and restate problems until agreement is attained on the one to analyze. Following that session, assemble technical information relevant to the problem and provide it

Table 1. Prerequisites for successful application of the cause-effect modeling method.

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1. Recognition that a foolproof method for modeling does not exist.
2. There must be firm agreement on the problem to analyze.
3. A trial run is necessary.
4. Adequate time must be allocated.
5. Contributors to modeling must participate in final review and approval of results.
6. The group size for modeling must be relatively small.
7. An experienced facilitator should guide a modeling exercise.

---

to the core group for review and further consideration. If consensus prevails at this stage, the appropriate problem is chosen.

Benefits of the trial run specified by prerequisite 3 include: (1) individuals in the core group will learn how to use the method to improve performance during the real runs; (2) important knowledge gaps can be documented; (3) needed information can be acquired prior to the real run; (4) complementary skills and disciplines can be designated for the real run; and (5) ideas for organizing information to improve modeling efficiency will be developed. Core group participants generally express the belief (sometimes adamantly) that they possess the collective knowledge to adequately address the problem. However, during trial runs there usually is recognition that individuals with supplemental skills must to be involved for a successful application.

A general rule for adequate time as described by prerequisite 4 is that at least three days are necessary for developing a basic model after the trial run is completed. When time exceeds three days, efficiency declines because of the intense concentration required. Beyond the initial three-day period, time will usually be required for model verification and final improvements. Modeling should be performed within a month or two after the trial run while interest levels are high. Also, the modeling exercise setting should be free from distractions and suitable for individual concentration and group interaction.

The importance of prerequisite 5 is that the approval by subject matter experts will give the completed model more credibility.

Concerning prerequisite 6, the size of a group responsible for modeling should be restricted to four to eight individuals. This size encourages all individuals to actively participate in evaluating the logic and technical justification of the model. Important ideas and opinions are more likely to be expressed and considered by a group of this size. One approach for a complex problem that might require involvement of more than eight individuals is to assign small groups of participants to develop different parts of a model. Then the separate parts can be assembled into a complete model.

The facilitator, indicated in prerequisite 7, should (1) ask questions to ensure that logic for all the model components is technically defensible, (2) encourage participants to freely share ideas in a collaborative exercise, and (3) ensure that all key information suggested by modelers is considered for incorporation in the model. Involvement of the facilitator as a technical expert is not recommended because of the need to concentrate on proper application of the method. Once a facilitator begins to function as a technical expert, effectiveness as a guide in the analysis is diminished. Two key roles of a facilitator are to change direction or emphasis when a dead end occurs and to emphasize important subjects when more detail is needed.

MODEL DESCRIPTION

Many factors contribute to environmental problems. Consider, for example, the deteriorated habitat in a coastal bay (Figure 1). Unless such complexity is reduced, analysis is impossible. One approach to reducing complexity is to designate a priority problem (e.g., one related to specific habitat or important fish and wildlife populations) to solve. Another approach is to designate a keystone problem (Williamson et al. 1987) that, if solved, will result in restoration of a healthy ecosystem and elimination or control of several problems.

Following agreement on a keystone or priority problem, a six-step modeling process (Figure 2) is followed. Step 1 consists of stating the problem. The problem statement for the hypothetical problem (Figure 1) might be: 70% of the submerged aquatic vegetation was lost in the last 15 years.

Step 2 involves categorizing major causes contributing to the problem by asking the question "what are the main causes of the 70% loss of vegetation in the last 15 years?" (Figure 3).

Step 3 consists of modeling problem causes. The information is assembled from right to left (Figure 4) with categories of causes as starting points. Prior to final agreement on causes, suggestions from participants in a modeling exercise are debated until a consensus is attained. To ensure that causes are logical (going leftward) the question "what causes this?" must be asked. For example "what is the cause of turbidity?" (Entry 2, Figure 4); answer: "plankton blooms and entry of sediment" (Entries 5 and 7). As a chain is constructed, specificity increases with each entry to the left until endpoint causes are identified. For example, the endpoint for the turbidity chain is

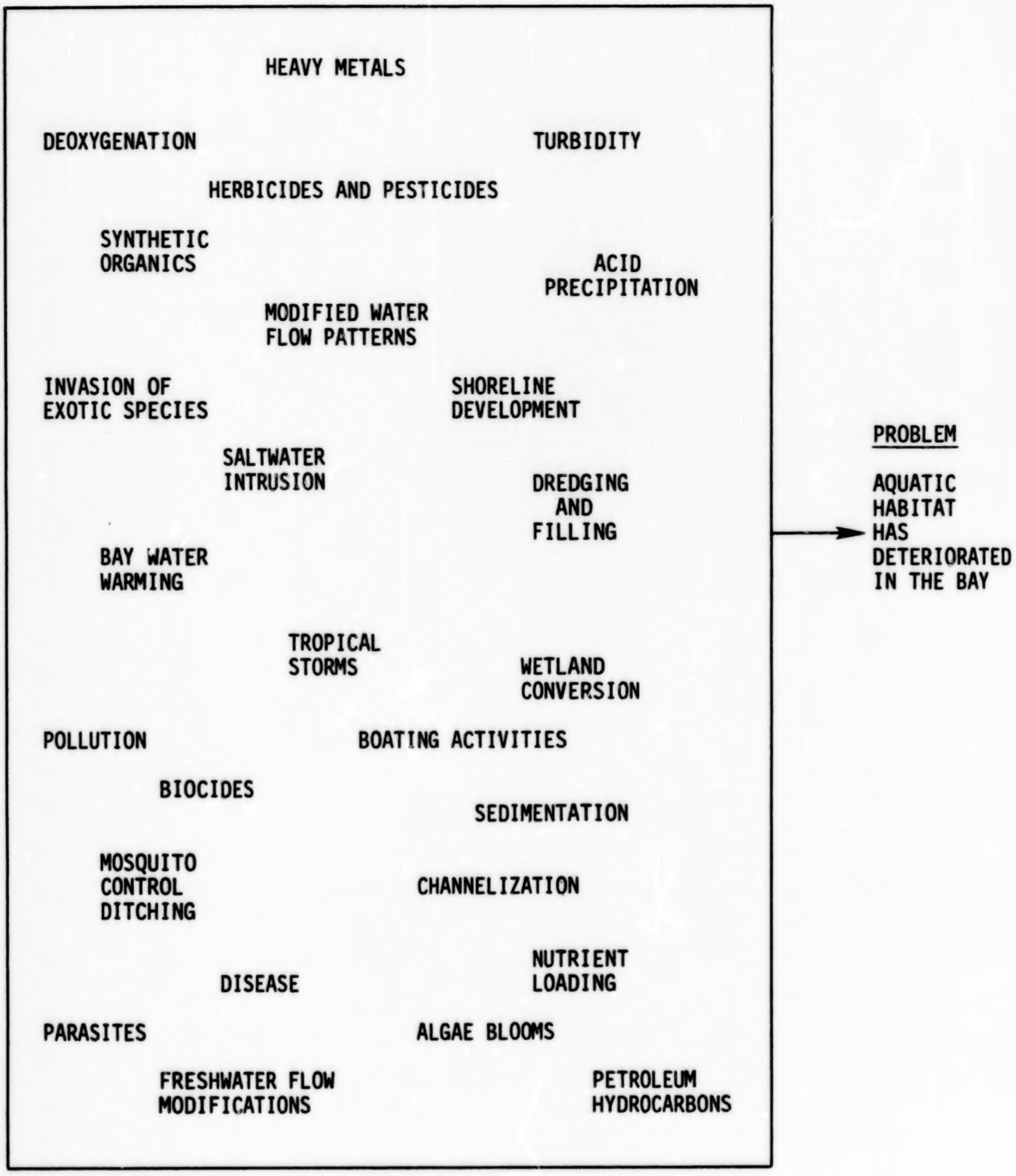


Figure 1. Some causes of aquatic habitat deterioration in a hypothetical coastal bay.

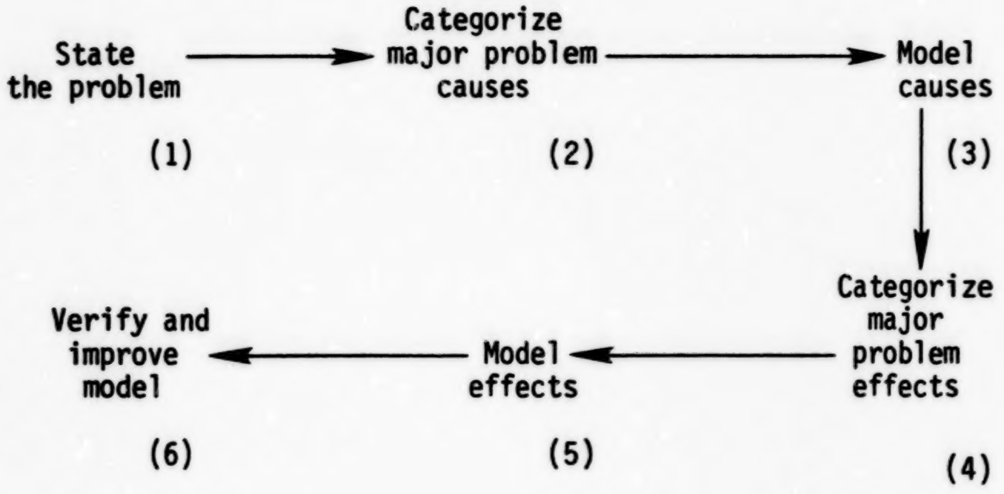


Figure 2. Steps for modeling causes and effects.

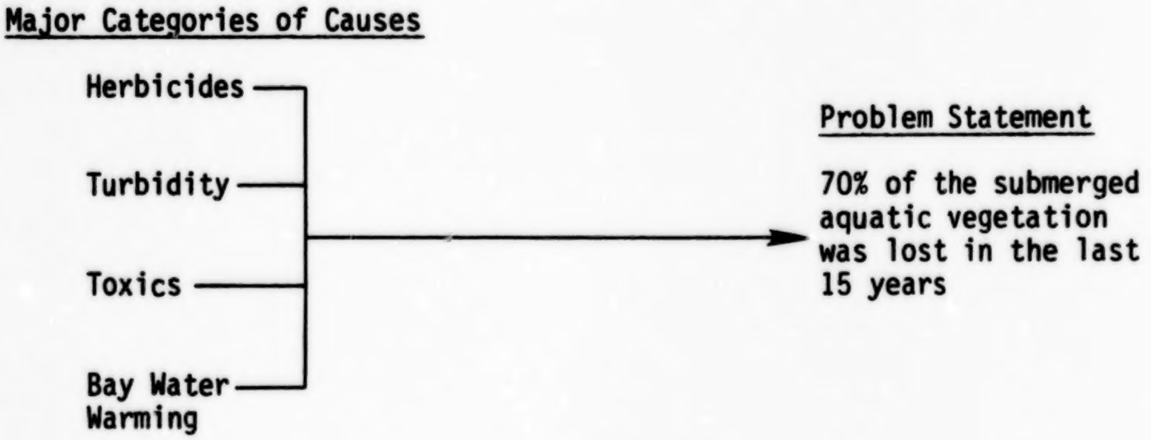

Major Categories of Causes
Herbicides
Turbidity
Toxics
Bay Water Warming
Problem Statement
70% of the submerged aquatic vegetation was lost in the last 15 years

Figure 3. Major categories of causes contributing to submerged aquatic vegetation loss.

adverse agricultural practices (Entry 9). Another important point is that a completed chain is a combination of causes and effects. For example, in the turbidity chain, each cause entry is followed to the right by an effect, e.g., one effect of nonpoint source runoff (Entry 8) is sediment entry (Entry 7). Mixing of causes and effects in this part of a model may confuse some participants. The difficulty can be overcome by emphasizing that the causes part of a model pertains to the time period before the problem is observed.

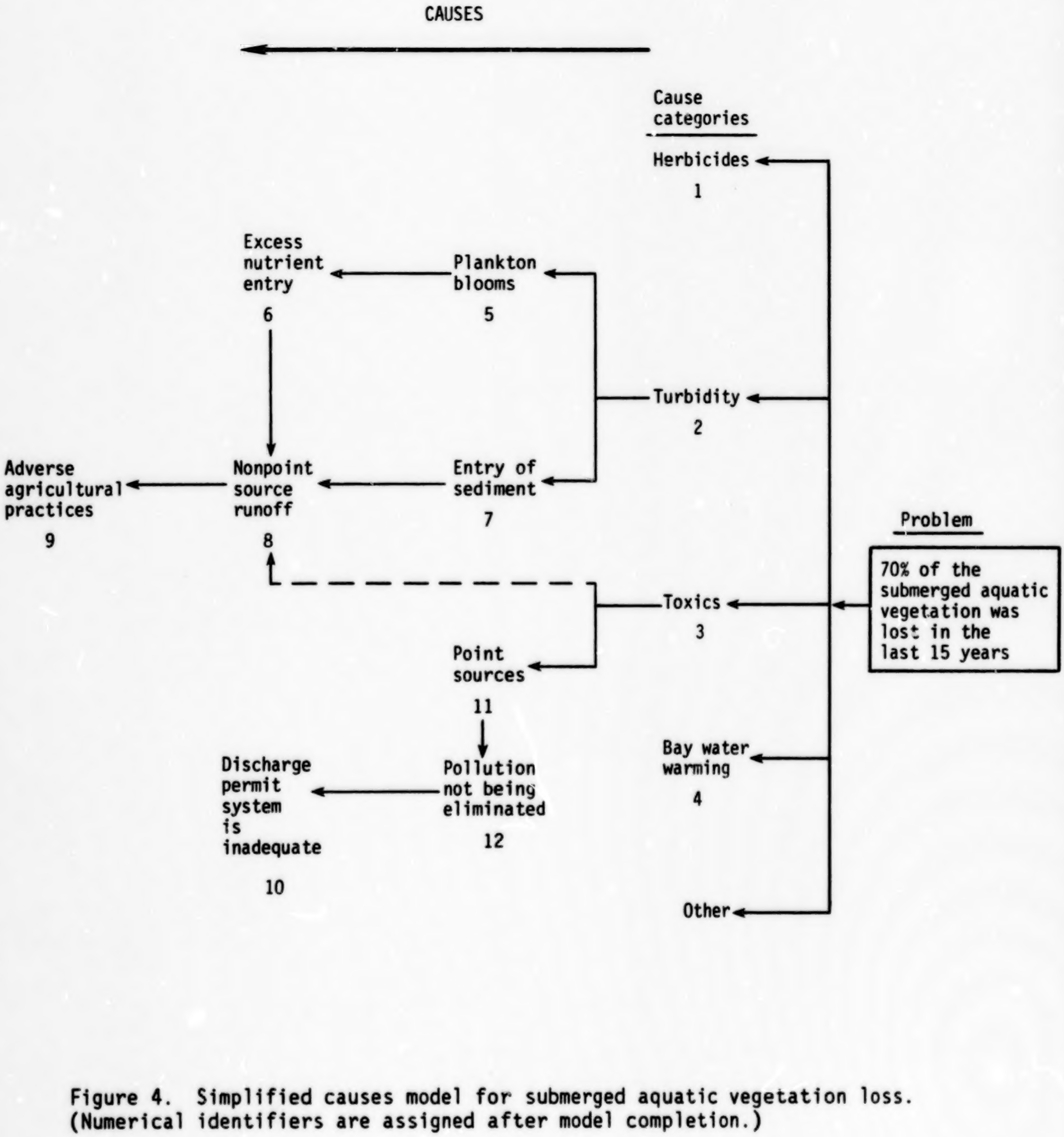


Figure 4. Simplified causes model for submerged aquatic vegetation loss. (Numerical identifiers are assigned after model completion.)

Step 4 requires categorizing the major problem effects as a starting point for the effects part of a model. These categories could be the same as the categories for the causes part of the model or something different (e.g., decreased protective habitat and macrophyte primary productivity), as in Figure 5.

Step 5 requires modeling of effects (Figure 5), with categories of effects as starting points. At each juncture working to the right the question "what is the effect of this?" is asked. For example, "what are effects of decreased protective habitat?" (Entry 1); answer: "there are three major groups of effects, i.e., less niches for prey species, reduced protective cover for immature sport and commercial fish, and less niches for invertebrates." Specificity for this part of the model increases rightward. For example, a terminal effect of decreased protective habitat (Entry 1) is reduced sport and commercial harvest of finfish (Entry 19). Like the causes part of the model, a completed effects chain is a combination of causes and effects, e.g., moving leftward a cause of decreased survival of sport and commercial fish (Entry 8) is increased predation (Entry 7).

Step 6 consists of model verification and improvement. The preferred form of verification is controlled experiments that have been identified as a result of the causes and effects modeling, but this will be impractical for many complex problems. The simplest form of verification is to document the rationale for cause-effects chains by responding to the question "how do we know this is true?" for each entry. One option is to rely on literature sources. Table 2 shows examples of verification documentation assembled for the hypothetical example (Figure 4). Another option is expert opinion or professional judgment. Flaws in the original logic can be detected and improvements can be made as a result of the verification process.

MODEL USES

When modeling is completed, causes and effects are separated (the information is classified), there is increasing specificity for each successive link in a chain (the information is ordered), and relationships of components in chains are documented (the information is associated). There are also four other important attributes (Table 3).

A completed model can be used to (1) provide a starting point and documentation for resolving interpretational conflicts between agencies, (2) determine additional information to obtain and analyses to perform to improve understanding, (3) determine categories of actions and specific tasks to "break" causal chains, (4) design mitigation for unavoidable impacts, and (5) establish a logical and defensible basis for developing a comprehensive management plan to deal with a problem.

Model results also can be applied to environmental impact statements and other such documents. Specifically, a modeling exercise can (1) promote coordination and effectiveness of specialists assigned as a team to prepare an

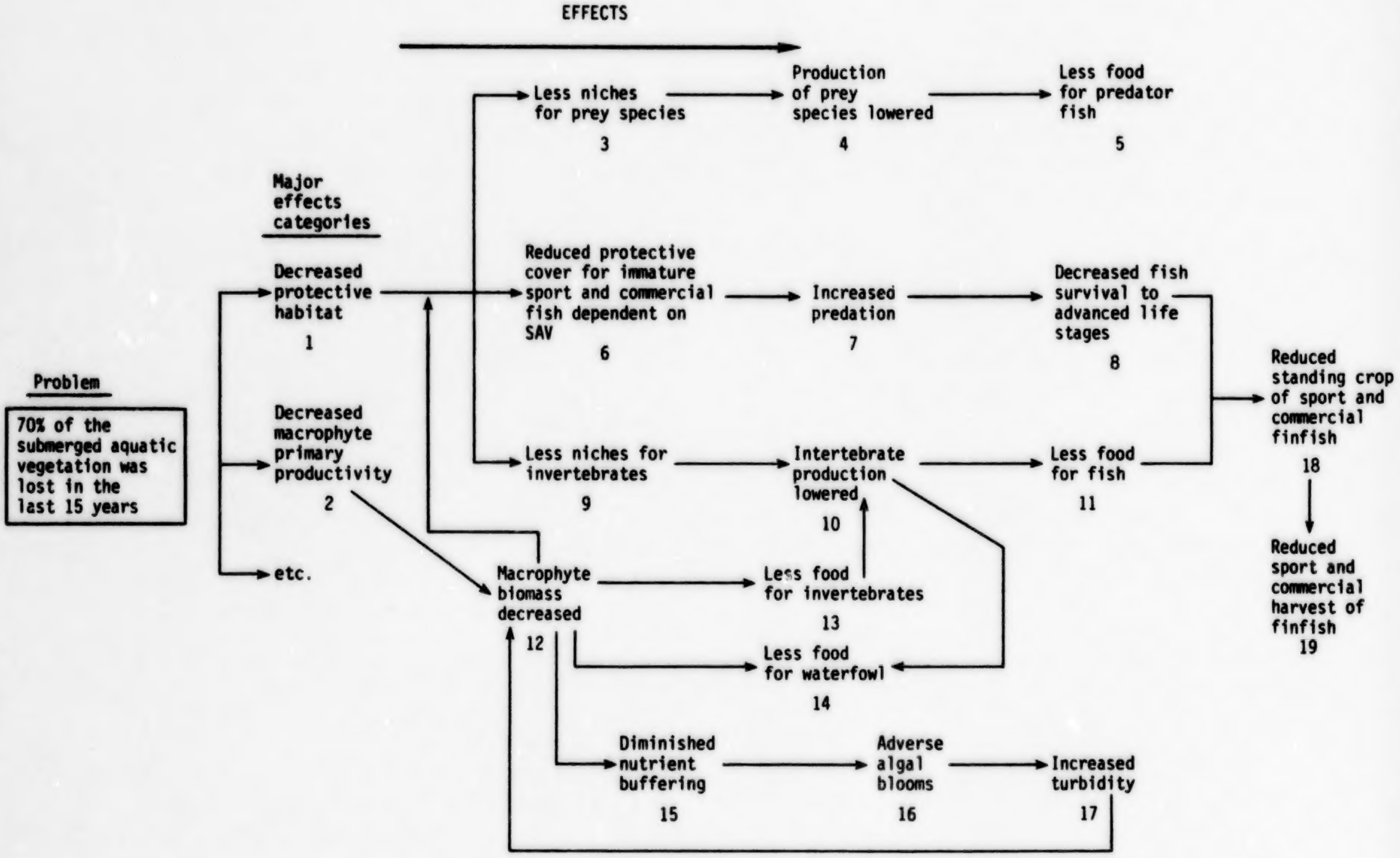

EFFECTS
Problem
70% of the submerged aquatic vegetation was lost in the last 15 years
Major effects categories
Decreased protective habitat
1
Decreased macrophyte primary productivity
2
etc.
Less niches for prey species
3
Production of prey species lowered
4
Less food for predator fish
5
Reduced protective cover for immature sport and commercial fish dependent on SAV
6
Increased predation
7
Decreased fish survival to advanced life stages
8
Less niches for invertebrates
9
Intertebrate production lowered
10
Less food for fish
11
Macrophyte biomass decreased
12
Less food for invertebrates
13
Less food for waterfowl
14
Diminished nutrient buffering
15
Adverse algal blooms
16
Increased turbidity
17
Reduced standing crop of sport and commercial finfish
18
Reduced sport and commercial harvest of finfish
19

Figure 5. Simplified effects model for the submerged aquatic vegetation loss problem. (Numerical identifiers are assigned after model completion.)

Table 2. Illustration of verification logic for problem causes. Documentation references are fictional and the cause components correspond with entries in Figure 4.

Cause components	Documentation	Indicator
1. Herbicides	Doe et al. (1979) reported that concentrations of herbicides in the bay are lethal to vegetation.	Concentrations of herbicide X ≥.05 ppm are lethal to widgeon grass and eelgrass (Jones and Smith 1985).
2. Turbidity	Doe (1980) reported that high turbidity is damaging vegetation.	Secchi disc readings are <0.5 m during spring and summer months in 25% of the bay. Submerged vegetation has been destroyed in these areas.
3. Toxics	Doe et al. (1983) reported that toxic substance A is damaging vegetation.	Toxic substance A concentrations ≥.025 ppm kill vegetation, and this concentration is exceeded 65% of the time.

environmental impact statement, (2) contribute to outlining subject matter to include in a document, (3) serve to specify individuals with supplemental skills who must be involved to successfully complete a project, (4) function as a framework for early resolution of environmental conflicts, and (5) be used as a basis for critiquing environmental impact statements completed by others.

TREATING CAUSES

Before priority actions to break causal chains can be specified, there must be agreement on the relative importance of causes. Options for deciding on the importance of causes include: quantitative methods, such as simulation modeling (Grant 1986), and qualitative methods based on expert opinion (e.g.,

Table 3. Attributes of cause-effect model results. Modified from Riggs and Inoue (1975b).

Attribute	Importance
1. Information is classified.	Causes and effects are separated. This promotes more effective problem analysis and understanding. Problem solving can be focused on treating causes, not symptoms.
2. Information is ordered.	Specificity within a causes or an effects chain increases with subsequent chain entries. This stepwise progression contributes to a systematic and structured analysis. The result is end points preceded by a documented chain of logic.
3. Information is associated.	Each entry in a model is shown in a position that is associated with other entries in a logic chain. Cross linkages from one chain to another are also documented to indicate functional relationships including clues to synergism.
4. Information and the analytical process are recorded.	Completed models are a record of the problem analysis. The thought process is documented for quick and easy reference, and there is open disclosure of analysis results. If results are contested, the record serves as a framework for resolving conflicts.
5. Both the analytical process and the model are comprehensive.	Comprehensiveness decreases chances for important information being overlooked. When a subject is lacking from an analysis, corrective adjustments can be made. It is also very difficult for "pet" interests that do not have a logical fit in the framework to be advocated and emphasized.

(Continued)

Table 3. (Concluded)

Attribute	Importance
6. Information in the model is verified.	Each entry in a model can follow the question "why is this true?" Then supporting evidence that might be in the form of published literature or accepted expert opinion can be documented. If documentation is not available, need for research or the acquisition and analysis of existing information can be recorded for remedial action.
7. Information in the model is summarizeable.	The model format is easy to summarize or present in a different form for effective communication. This is important because for some circumstances (e.g., for individuals who dislike diagram models) the information can be easily assembled in another form. Regardless of the form chosen the model can be used as an outline.

Delphi technique [Delbecq et al. 1975; Linstone and Turnoff 1975; Crance 1987], nominal group technique [Delbecq et al. 1975], and voting). If the resources are available, quantitative methods are preferred. If not, qualitative methods are recommended. Although methods based on opinion might not be accepted as readily, they can be as general, realistic, and accurate (but not as precise) as more sophisticated methods, provided that qualified experts are involved. For example, Georgoff and Murdick (1986) evaluated 20 of the most common forecasting techniques used in industry. The techniques ranged from those in the professional judgment category to mathematically sophisticated ones. Surprisingly, methods in the expert opinion category seemed to be as accurate as other methods when qualified experts were involved.

The use of voting as a method to estimate importance of causes has pitfalls. The likelihood for error is increased if unqualified modelers participate, and dominant individuals can cause other voters to yield instead of exercising independent judgment. One voting approach is to require each expert to independently partition 100 points according to perceived levels of importance (Table 4). It is assumed that that averages (e.g., $\overline{X}$ for turbidity = 63%) are acceptable estimates. However, as stated earlier, there

Table 4. Examples of scoring by six experts. Average scores would be the same as percentages.

Cause	Scores assigned by six experts						Total score	$\bar{X}$
	1	2	3	4	5	6		
Herbicides	10	25	17	18	17	29	116	19
Turbidity	70	75	50	60	63	61	379	63
Toxics	10	0	30	12	15	10	77	13
Bay water warming	10	0	3	10	5	0	28	5
								100

are limitations. For illustrative purposes, suppose that two experts were to assign respective scores of 0 and 100. The average would be (0 + 100)/2 or 50%. However, the wide range of opinion would cause the score to be controversial. Conversely, if the experts' scores were 45 and 55, the average, (45 + 55)/2 or 50%, would be more indicative of reasonably close agreement. One option for evaluating the degree of agreement or variance of expert opinion, assuming that all the experts are equally knowledgeable, is to use rank correlation (Kendall 1962). Results might be accepted if, for example, there is evidence that a prestated level of agreement (e.g., 75%) exists.

Regardless of the method used to specify the relative importance of causes, certain limitations apply: Elimination of uncertainty will be virtually impossible, and most decisions will have to be based predominantly on professional judgment.

Following the decision concerning the relative importance of causes, suppose that the experts agreed that agricultural practices were the principal cause of nutrient and sediment entry (Figure 6). The logical choice of actions following this agreement would be to improve agricultural practices to control nonpoint-source runoff and reduce nutrient and sediment input to nonharmful levels. It might also be possible to specify a management action to influence more than one chain. For example, perhaps improved management practices for agriculture could also be applied to lessen the influx of toxics (Entry 3, Figure 4) in addition to sediment and excess nutrients.

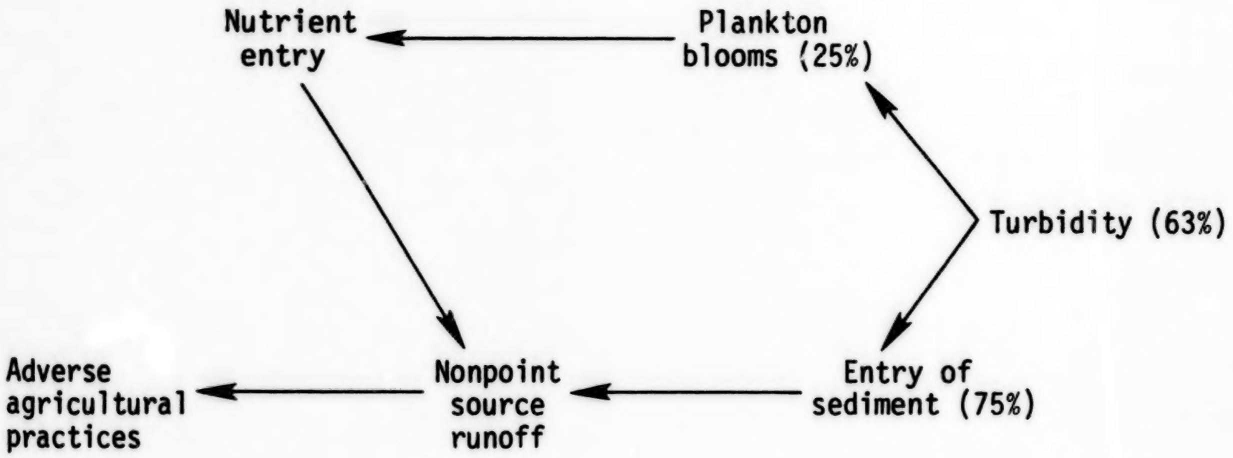


Figure 6. Percentage contributions of environmental factors to turbidity.

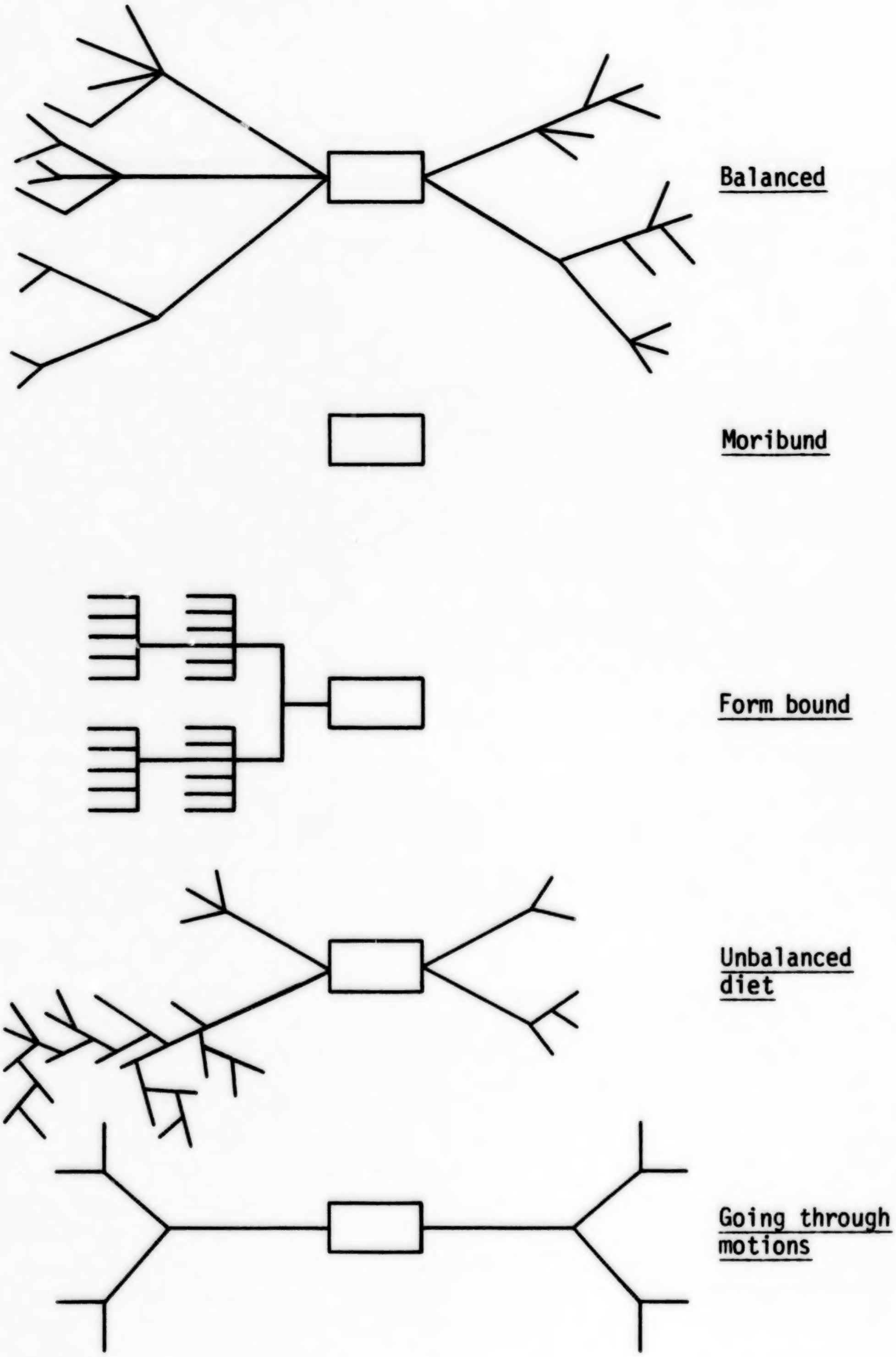
DIAGNOSING MODEL APPLICATION DIFFICULTIES

The pattern of modeling results can be used for diagnostic purposes (Figure 7). When a balanced analysis is performed, there should be enough branching in the model to indicate that appropriate effort was expended to understand the problem and that both causes and effects were sufficiently considered.

A moribund pattern occurs when there is little or no modeling progress beyond the problem statement. Reasons may include lack of understanding of the modeling methods; disagreement concerning the problem; participants' lack of interest, enthusiasm, imagination, and technical skill; and disruptive interpersonal relations.

The form-bound pattern can be caused by some of the same causes contributing to the moribund pattern. Reasons for concentrating on form may include inadequate understanding of the modeling process by participants or excess control by a dominant individual. When excess control occurs, individuals may be reluctant to contribute because they do not want their ideas to be attacked or ignored. As a defense mechanism most of the energy, therefore, is spent on form. If a dominant individual is detrimental to progress, he or she should be replaced with an individual who cooperates in a group setting.

An unbalanced diet pattern can be caused by lack of imagination and technical skills to perform the analysis. Limited time for an analysis can result in inadequate attention to completing important model branches.



Balanced

Moribund

Form bound

Unbalanced diet

Going through motions

Figure 7. Diagnostic patterns for a causes and effects model. Patterns were modified from Riggs and Inoue (1975b) and Erickson (1981).

A going through the motions pattern may be attributed to lack of interest, enthusiasm, imagination, and technical skill within a group. The best prevention is to carefully select individuals prior to an analysis to ensure that they have the necessary traits and skills to contribute to a successful application.

Preventive and corrective measures (Table 5) can be taken to prevent a modeling exercise from failing.

TECHNICAL LIMITATIONS OF THE METHOD

Most analytical methods, including this one, have technical limitations. Witmer (1985), for example, listed problems applicable to flow diagrams, a general category that includes this method (Table 6). A special limitation of this method is the difficulty in proving causality. Prior to concluding that there is reasonable evidence for causality, model linkages must be carefully evaluated.

Four main cues to causality that Einhorn and Hogarth (1987) described for business-related problems are appropriate: temporal order, proximity, correlation, and similarity. Temporal order exists when there is documentation that causes preceded effects. Proximity refers to closeness in time between causes and observed effects. The rationale is that with time lapse, there is always more uncertainty concerning accurate interpretations of importance of past events in contributing to a current problem. Correlation is established if there is documented evidence that effects are indeed dependent on causes. Similarity relates to likeness in scale, duration, and time of occurrence. Scale means that the relative degree of the impact should correspond with the intensity of the cause. If correspondence is lacking, interference from other causes is probably operating to preclude a direct cause and effect relationship. Accordingly, if an effect is worse than otherwise expected, multiple causality is probable. Duration is evident when causes and effects occur within a compatible timeframe. For example, the impact period of a nonpersistent herbicide should terminate when contamination ends, assuming lack of latent effects. Time of occurrence refers to an effect being logically associated with a cause that occurred during a preceding time period. Suspected mortality from a contaminant known to require a specific period (e.g., 20 days) for lethality to occur would be an example. If mortality is observed within five days, a different contaminant would be the cause if field conditions mimic those for which lethality was originally documented.

Einhorn and Hogarth (1987) give an example of application of these criteria to an eighteenth-century hypothesis that sunspots caused changes of stock market prices. The hypothesized causal chain was that sunspot activity caused altered weather patterns that impacted agricultural production and profits to eventually influence stock prices. All cues for direct linkage between sunspots and stock prices were not met, however. Proximity could not be documented because there was a pronounced time lag until stock prices were impacted, and similarity (likeness in scale, duration, and time of occurrence)

Table 5. Diagnosing modeling problems. Modified from Erickson (1981) and Riggs and Inoue (1975b).

	Resulting model				
Cause	Moribund	Form-bound	Unbalanced	Going through motions	Preventive and corrective measures
Analytical process not understood	X	X			Provide adequate advance training to ensure that individuals understand the modeling process. If the problem becomes evident after an analysis begins, stop the exercise until additional training is given.
Disagreement on problem	X				Allocate adequate time before modeling to attain agreement on a clearly defined problem. If modelers become bogged down after an exercise begins, take time out to attain agreement.
Lack of interest and enthusiasm	X	X		X	Ensure that willing and enthusiastic participants are involved. If the problem occurs after an exercise begins, determine if there is a roadblock affecting attitudes. It might be necessary to replace some members of the group with other individuals.
Lack of imagination	X	X	X	X	Individuals should be chosen in advance who are imaginative and skilled at conceptualizing. If it becomes apparent that the correct individuals were not chosen, replace them and start over.
Overemphasis on form instead of results		X			Provide adequate advance training to ensure that individuals understand the analytical process. If this problem develops, correct it after finding out if more training is required or if it is caused by an overbearing individual who wants to exercise stifling control at the expense of group participation.
Group lacks technical skills to perform analysis	X	X	X	X	Prior to an exercise carefully select individuals for participation who have technical depth and breadth. If the problem occurs, supplement the group with individuals with the needed skills.
Group cannot work together and excess time is spent on disagreement	X	X			Expend care in advance to select individuals who can work together. If incompatibility is demonstrated, replace uncooperative individuals and start over.

Table 6. Potential limitations of the method. Modified from Witmer (1985).

Limitation	Comment
Not quantitative.	There are important benefits from using qualitative models. For example, they can be used to attain conceptual understanding of a problem prior to determining a logical quantification approach. For many environmental problems, precise and accurate quantification is infeasible.
Does not readily allow for multiple projects or regional actions.	If it is determined that several projects (e.g., four power plants) contribute to a problem, model information could be used to design studies or analytical approaches to evaluate impacts. Then, professional judgment and use of the best information available could be used to attain agreement on the addition of other projects to remain within system tolerance limits.
Not necessarily comprehensive and may overlook important processes or elements.	Incomplete models can be caused by failure to involve the necessary complement of disciplines in modeling. Models should be reviewed by qualified experts prior to completion. Also, models should be upgraded when new information becomes available.
Difficult to deal with non-ecological impacts.	Success in dealing with this limitation depends on a commitment to address nonecological factors and to involve individuals in modeling with skills to adequately analyze the factors. This limitation is particularly true if care is not taken to consider the full dimension (e.g., social, political, economic) of factors associated with a problem.

(Continued)

Table 6. (Concluded)

Limitation	Comment
Does not address impact significance or magnitude, only impact occurrence.	One approach for overcoming this limitation is to use mapping/overlays and simulation modeling to develop significance and magnitude information. We recommend conducting causes and effects modeling before beginning simulation modeling.

could not be conclusively established. The problems precluded a firm conclusion that a direct causal link between sunspots and stock prices existed. This demonstrates that each cause and effect model must be carefully evaluated before its final acceptance as a valid representation of reality. It is particularly essential to evaluate and verify a model when decisions are made on actions for "treating causes" to solve a problem. Obviously, if an incorrect, relatively insignificant, or nontreatable cause is identified, attempts to deal with it to solve a problem will fail.

Besides suggesting cues of causality, Einhorn and Hogarth (1987) recommended approaches for improving understanding of factors contributing to a problem. These approaches include the following: (1) do not rely solely on one cue, (2) go against cues sometimes, (3) assess causal chains, and (4) generate and test alternative explanations. Blind acceptance of model results may prevent consideration of faulty reasoning. Going against cues is desirable because it is one way to promote creative thinking, especially when striving for an explanation of a complex outcome.

The importance of assessing causal chains pertains to recognition that the relative importance of chains can differ, the strength of a chain is limited by its weakest link, and there usually is an inverse relationship between length and strength. Also, there can be an erroneous perception that models with a complex maze of chains are closer to reality than simple ones.

Generating and testing alternative explanations requires receptivity to new and perhaps controversial concepts. Receptivity is essential because for most complex environmental problems, interpretations of causality will depend heavily on conceptualization. Explanations derived from carefully controlled experiments that accurately duplicate field conditions will usually be infeasible. Therefore, solving of most complex environmental problems will require trial and error. When erroneous concepts are detected and replaced through the process, the knowledge base will increase to make management solutions more feasible.

CONCLUSION

In our experience with applying this method, we often encountered preconceived attitudes that modeling would not succeed. The most common attitude was that the task was too difficult, not worth the work and time required, and useful results could not be produced. With few exceptions, after the method was explained and application examples were discussed, skeptics became willing to try.

Another attitude, particularly for individuals lacking modeling training and experience, was the belief that they did not have required skills to perform the work. This belief was usually dispelled after participation in a trial application. Skeptical individuals learned that complex and disjunct information could be organized with reasonable ease into a useful model when qualified experts contribute and an experienced facilitator assists.

Reluctance of individuals to engage in an interdisciplinary group effort also occurred because relatively few individuals had formal training and experience in interactive, group problem solving; they thought that involvement of individuals in other disciplines might challenge cherished ideas and activities (e.g., favored research projects or pet peeves) or that their ideas might be discredited if subjected to close scientific scrutiny. However, most individuals recognized advantages of a group effort when modeling was performed. The major reason was that it became apparent that application of collective knowledge enhanced chances for understanding and designating viable solutions to problems. Regarding cherished ideas and activities being challenged, a major benefit of the group approach was that low priority and relatively unimportant items did not survive close scrutiny. The result was disadvantageous to the vested interest motives of some individuals, but the payoff was increased efficiency and effectiveness.

Reluctance of model participants to request assistance from individuals in other organizations was also a problem, for two reasons: concern that a request would be interpreted as scientific ineptness and perceived loss of control to other organizations. The first factor was particularly true if the requesting organization was primarily responsible for managing an impacted resource, or if it was perceived to be the focal point of expertise for the resource. Concerning the second factor, based on experience with multiorganization representation, distinct advantages were observed. For example, for complex problems a single organization seldom has the authority, expertise, and funding to unilaterally solve a problem. Conversely, collective involvement can result in agreement on logical divisions of responsibility for a comprehensive and effective problem solving program. Also, if a problem is perceived to be important by the public, multiorganizational involvement and support increases chances for implementation of an effective program.

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50272-101

REPORT DOCUMENTATION PAGE	**1. REPORT NO.** Biological Report 89(4)	**2.**	**3. Recipient's Accession No.**

4. Title and Subtitle
Guidance for modeling causes and effects in environmental problem solving

5. Report Date
October 1988

6.

7. Author(s)
Carl L. Armour

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
National Ecology Research Center
U.S. Fish and Wildlife Service
Creekside One Building
2627 Redwing Road
Fort Collins, CO 80526-2899

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
U.S. Department of the Interior
Fish and Wildlife Service
Research and Development
Washington, DC 20240

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

Environmental problems are difficult to solve because their causes and effects are difficult to analyze and understand. The guidance pertains to an easy to understand and apply procedure for organizing and simplifying complex information into a cause and effects model through an interdisciplinary exercise. Information is included on prerequisites to help ensure completion of a useful model, applications of model information in environmental assessment and problem solving, diagnosing and correcting modeling problems when users encounter difficulties, and technical limitations of the approach. In relationship to application of model results to environmental impact statements and other documents, some uses include development of an outline for a document to be written, and serving as a technical framework for evaluating adequacy of existing documents.

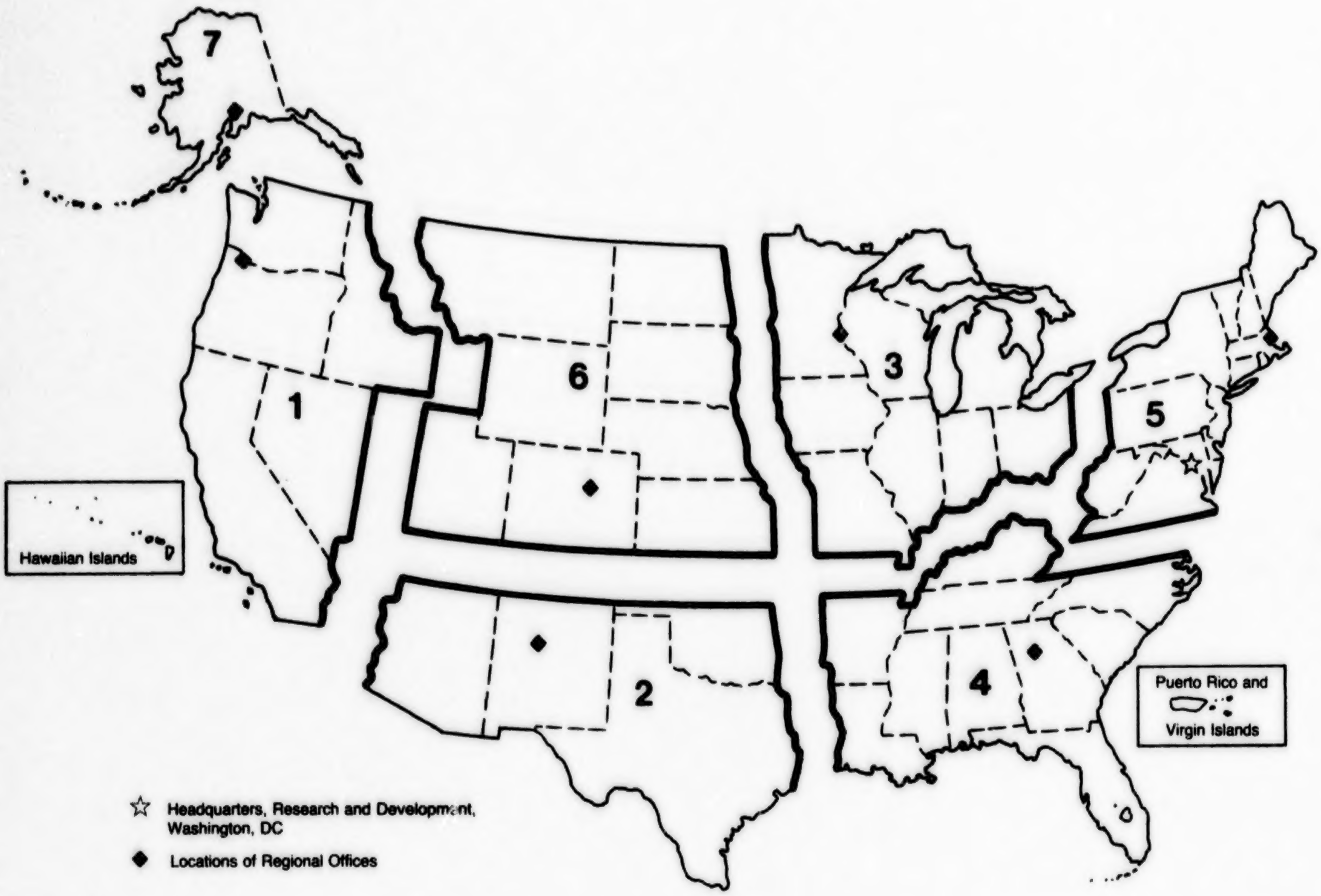
17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms
Causes and effects modeling
Environmental modeling

c. COSATI Field/Group

18. Availability Statement Release unlimited	**19. Security Class (This Report)** Unclassified	**21. No. of Pages** 21
	20. Security Class (This Page) Unclassified	**22. Price**

22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Hawaiian Islands
Puerto Rico and Virgin Islands
☆ Headquarters, Research and Development, Washington, DC
◆ Locations of Regional Offices

REGION 1
Regional Director
U.S. Fish and Wildlife Service
Lloyd Five Hundred Building, Suite 1692
500 N.E. Multnomah Street
Portland, Oregon 97232

REGION 2
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 1306
Albuquerque, New Mexico 87103

REGION 3
Regional Director
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, Minnesota 55111

REGION 4
Regional Director
U.S. Fish and Wildlife Service
Richard B. Russell Building
75 Spring Street, S.W.
Atlanta, Georgia 30303

REGION 5
Regional Director
U.S. Fish and Wildlife Service
One Gateway Center
Newton Corner, Massachusetts 02158

REGION 6
Regional Director
U.S. Fish and Wildlife Service
P.O. Box 25486
Denver Federal Center
Denver, Colorado 80225

REGION 7
Regional Director
U.S. Fish and Wildlife Service
1011 E. Tudor Road
Anchorage, Alaska 99503

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8-27-91